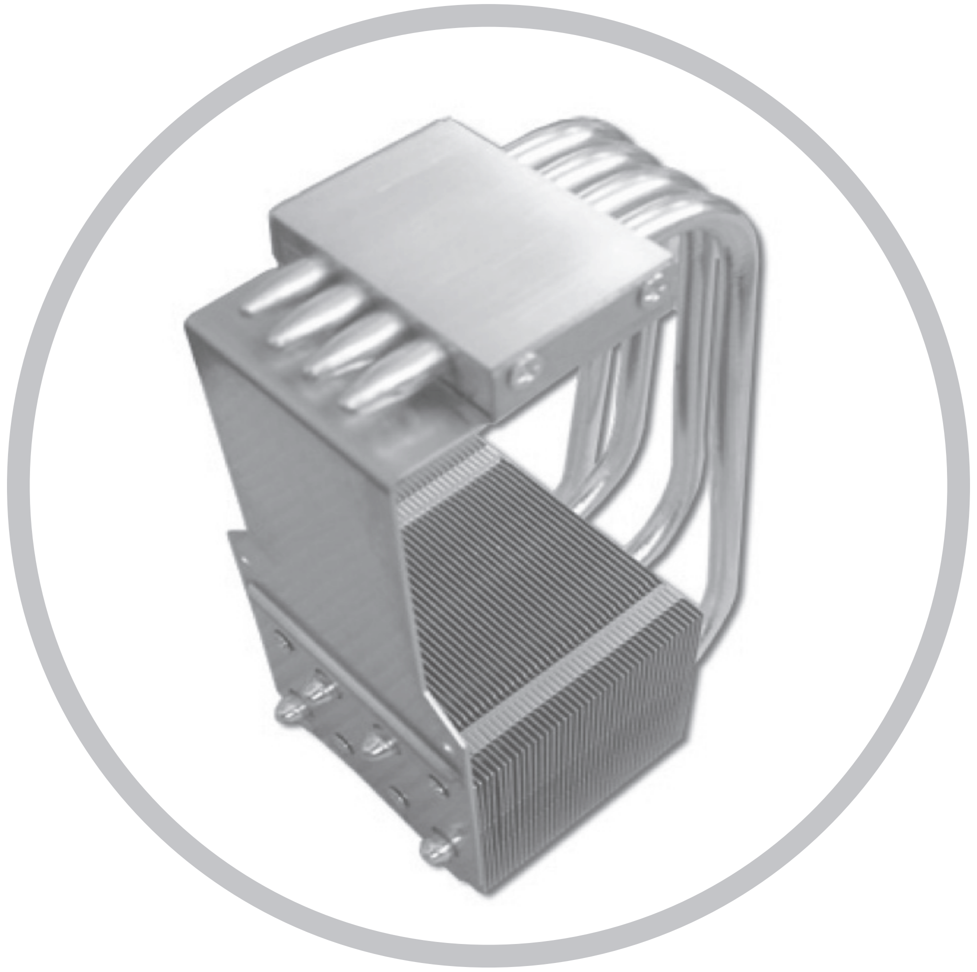
PHASE CHANGE

Heat Pipe Selection Guide *126–131*
Vapor Chamber Design Guide *132–137*

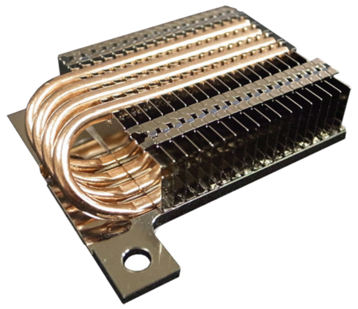


Fluid Phase Change applications, often referred to as "re-circulating," use closed loop heat pipes to transfer heat quickly through evaporation and condensation within the heat pipe. Because of their high thermal efficiency, heat pipes are often designed into advanced heat sink technologies when increased thermal density or physical size restrictions exist. This similar process is utilized in vapor chamber technology as well.

HEAT PIPE SELECTION GUIDE

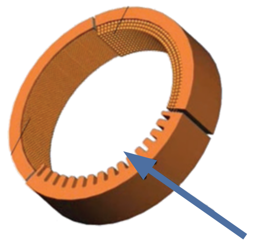
HEAT PIPE INTRODUCTION

Heat pipes are used to transport heat over a distance with very low thermal resistance. This is very helpful when small or distant heat sources need to be dissipated over a larger area or moved to a remote heat exchanger. Heat pipes are a **Fluid Phase Change application**, often referred to as "re-circulating," because they use a closed loop to transfer heat quickly through evaporation and condensation within the heat pipe.

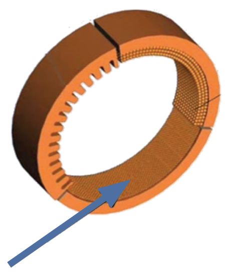


Heat pipes do not actually dissipate the heat to the environment, but serve to move heat efficiently within a thermal system. A heat pipe is a copper tube with an internal wick structure that is sealed on both ends with a small amount of water inside. As heat is applied to the pipe, the water will boil and turn to a gas, which then travels to the colder section of the heat pipe where it condenses back to a liquid. It is the evaporating and condensing of the water that form a pumping action to move the water (and thus the heat) from end to end of the pipe. There are many types of wick structure that can be used within the heat pipe and they are generally classified into grooved, mesh, powder and hybrid.

A **grooved heat pipe** is a copper tube with a series of shallow grooves around the internal perimeter of the heat pipe. While the water is a liquid, it travels in the grooves and while it is a vapor it travels in the open space of the pipe. Grooved pipes can be used in horizontal orientations, but are very limited in performance if used above 15° out of horizontal.



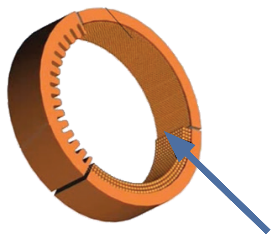
GROOVED HEAT PIPE



MESH HEAT PIPE

A **mesh heat pipe** is a smooth wall copper tube with a woven copper mesh installed along the interior of the pipe. The mesh is designed to remain in contact with the walls of the pipe in areas where the pipe may be bent or flattened. Mesh pipes can be used in horizontal and orientations up to 30° out of horizontal.

A **powder wick heat pipe** can also be known as a **sintered heat pipe**. During the manufacturing process a mandrel is installed in the center of the pipe and copper powder is poured into the pipe around the mandrel. After the powder is sufficiently packed, the parts are placed into a sintering oven. Once at temperature, the copper powder will stick to the pipe and to itself, forming numerous internal pockets like a sponge. Because of the small pocket sizes, sintered pipes can efficiently move the water and can be used horizontally, vertically and all points in between including upside down.



POWDER WICK HEAT PIPE

Wakefield-Vette primarily sells sintered, or powder, style heat pipes due to their higher performance and the best heat pipe for your application.

WHY USE HEAT PIPES?

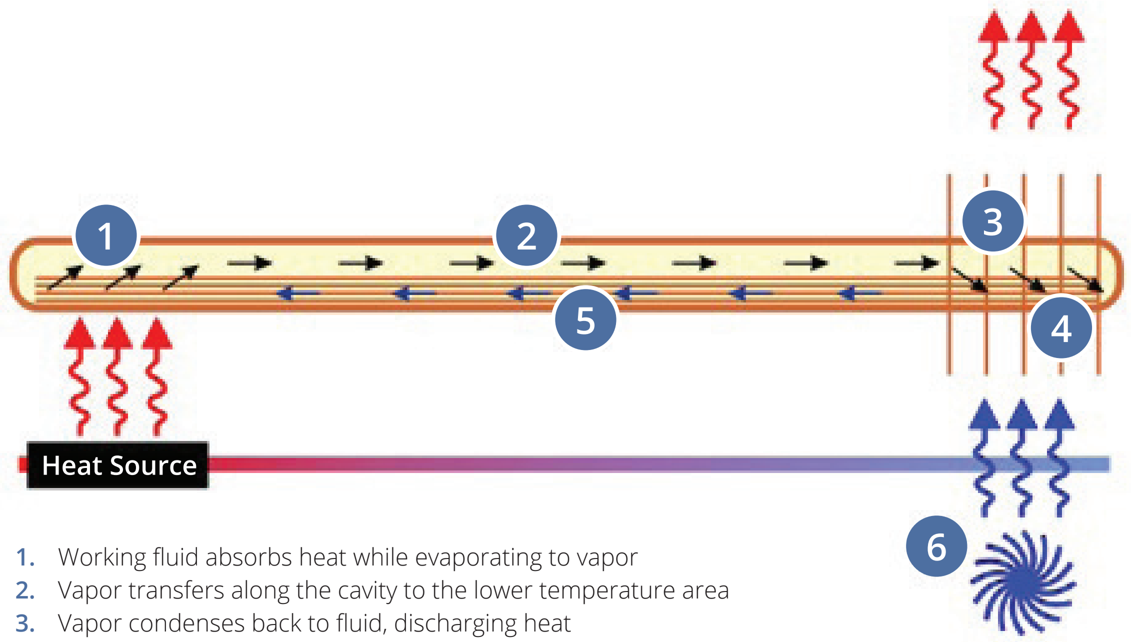
Heat pipes have proven to be robust and reliable over many years in these types of applications. The next section will give more technical detail on the performance of heat pipes depending on diameter, length, and angle of use. Many thermal systems benefit from the addition of heat pipes, especially when heat sources are dense and/or remote to the final heat exchanger. Computer applications, such as processors, graphics cards and other chip-sets, have high thermally dissipated power in a small area. Fan heat sink combinations used in these applications can offer high-performance dissipation to the ambient, but much of the battle is to bring the heat to the heat exchanger with as little temperature change as possible. Heat pipes excel at this and can transport large heat loads from small areas with very little temperature difference.

Heat pipes are used in many harsh environments such as:

- Telecommunications
- Aerospace
- Transportation
- Computers and Data Centers

KEY FEATURES
• Material: Copper
• Wick Structure: Powder Sintered Copper
• Light Weight
• Versatile with high thermal performance

HOW HEAT PIPES OPERATE



1. Working fluid absorbs heat while evaporating to vapor
2. Vapor transfers along the cavity to the lower temperature area
3. Vapor condenses back to fluid, discharging heat
4. Fluid is absorbed by the sintered/powdered wick structure
5. Fluid returns to high temperature end via capillary force in the wick structure
6. Natural or forced convection air flow dissipates excess heat to ambient

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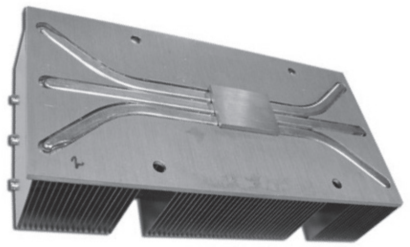
HEAT PIPE SELECTION GUIDE



HEAT PIPE BASICS

When selecting the diameter and length of heat pipe it is important to consider the orientation with respect to gravity and overall heat load for the thermal system. The transport of vapor within the heat pipe is responsible for the thermal conduction from one end to the other. A larger diameter heat pipe can transport more vapor, translating into a larger heat carrying capacity. Also, the orientation of the pipe with respect to gravity plays a role in the thermal capacity of a heat pipe.

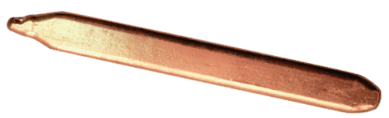
When selecting the diameter and length of heat pipe it is important to consider the orientation with respect to The thermal capacity is increased when the heat source is lower than the condenser (or ambient heat exchanger) because gravity assists the return of condensed water back to the heat source. The opposite is also true as the thermal capacity is reduced when the condensed water must move by capillary forces back to the heat source against gravity. This effect is exaggerated with longer heat pipes and testing has shown that the gravity effect can nearly the double the thermal capacity in the advantageous direction and cut the capacity in half in the deleterious direction from the heat pipe in the horizontal orientation. In the short heat pipe extreme (3"-4" length), this effect is nearly zero, so please consult with Wakefield-Vette engineers to find the right solution for your application.

HEAT PIPE BASICS

- Picking the correct pipe
- Transport
- General parameters
- Bending
- Flattening

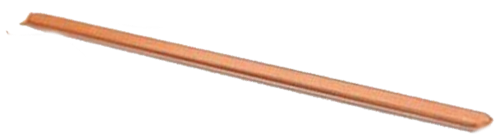
MAXIMUM HEAT TRANSFER TABLE (POWDER TYPE) — HEAT PIPE LENGTH = 150MM

Qmax Type	Out Diameter Φ3mm	Out Diameter Φ4mm	Out Diameter Φ5mm	Out Diameter Φ6mm	Out Diameter Φ8mm
Flatten t=2.0mm	13.2 W	16.6 W	20.5 W		
Flatten t=2.5mm	13.2 W	19.8 W	23.6 W	34.0 W	51.5 W
Flatten t=3.0mm	13.1 W	19.8 W	28.4 W	39.2 W	67.5 W
Round Pipe	13.2 W	19.8 W	30.1 W	48.1 W	74.2 W



MAXIMUM HEAT TRANSFER TABLE (POWDER TYPE) — HEAT PIPE LENGTH = 250MM

Qmax Type	Out Diameter Φ3mm	Out Diameter Φ4mm	Out Diameter Φ5mm	Out Diameter Φ6mm	Out Diameter Φ8mm
Flatten t=2.0mm	7.2 W	10.1 W	12.2 W		
Flatten t=2.5mm	8.1 W	11.2 W	13.1 W	16.5 W	23.0 W
Flatten t=3.0mm	8.2 W	12.1 W	14.1 W	22.0 W	37.0 W
Round Pipe	9.0 W	12.3 W	15.6 W	29.3 W	45.0 W



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FLATTENING HEAT PIPES

Flattening is another aspect of heat pipes that effect their performance. Often it is necessary to flatten a heat pipe to fit into a desired shape or gap or to increase the contact area of the pipe with the heat. Since flattening reduces the effective cross-sectional area of the round pipe, the thermal capacity is reduced, just as if a smaller diameter pipe was being used. The larger diameter of the starting heat pipe, the larger reduction of thermal capacity is seen when flattening. Also, the larger diameter pipes cannot be flattened to the same ultimate dimension as the smaller pipes without disrupting heat flow altogether. This is also true for bending of pipes. The radius of bending is usually 3-5x the diameter of the heat pipe depending on the pipe diameter and the process of bending the pipe. The potential danger is to collapse the pipe, effectively cutting off vapor and thermal transport.

SIZE OF FLATTED HEAT PIPES

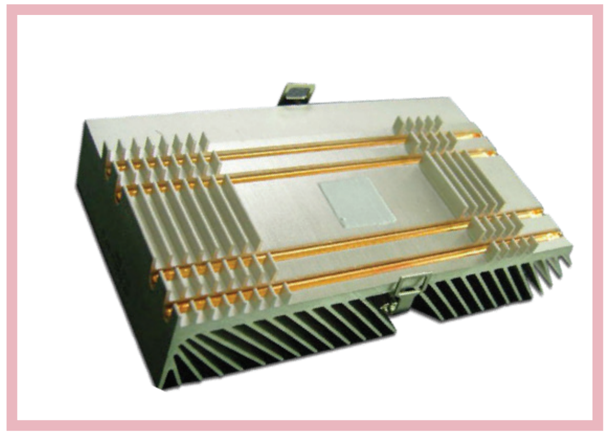
Diameter (mm)	Thickness (mm)	Width (mm)	Tolerance (mm)
4mm	3	4.65	+/- 0.15
	2.5	5	+/- 0.15
	2	5.23	+/- 0.15
5mm	3.5	5.97	+/- 0.15
	3	6.25	+/- 0.15
	2	6.83	+/- 0.15
6mm	4	7.3	+/- 0.15
	3.5	7.58	+/- 0.15
8mm	6	9.35	+/- 0.15
	5	9.95	+/- 0.15
	4	10.5	+/- 0.15
	3	10.99	+/- 0.15

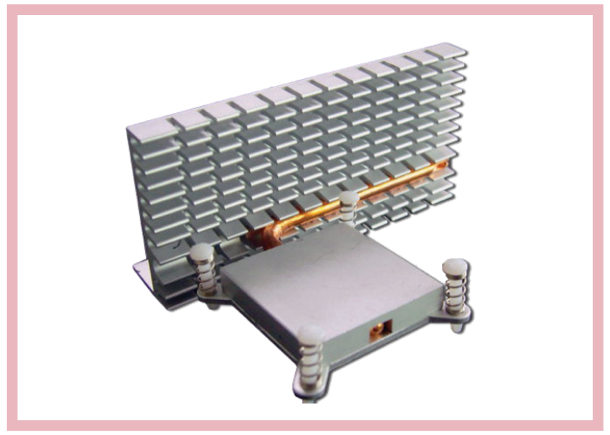
Bending radius for heat pipes of different diameters depending on the method of bending.

BENDING

By Hand:
- 4mm: 4 x diameter
- 6mm: 4 x diameter
- 8mm: 5 x diameter

Tooling:
- 4mm: 3 x diameter
- 6mm: 3 x diameter
- 8mm: 4 x diameter





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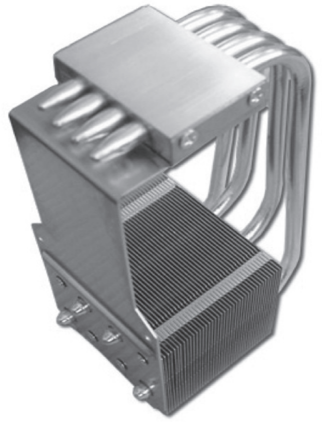
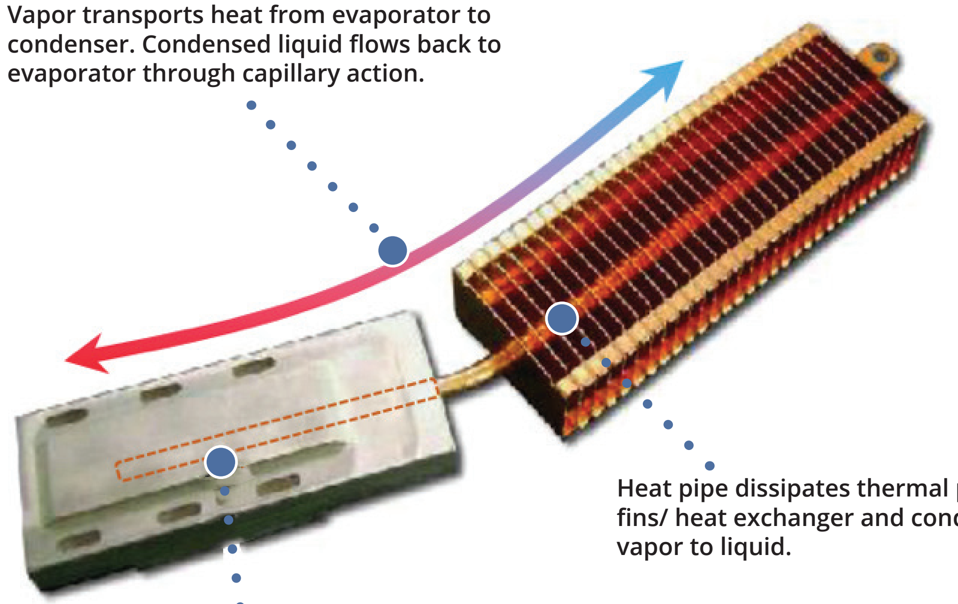
HEAT PIPE SELECTION GUIDE



HEAT PIPE ASSEMBLIES

Interfacing heat pipes with plates and heat exchangers is predominately about maximizing contact area while adhering to the flattening and bending guidelines mentioned above. In most cases, the heat pipes are slotted into channels/grooves in the plate to maximize contact. The heat pipe can be secured into the groove using solder or thermal epoxy, which also augments the contact area of the heat pipe. The heat pipe can also be clamped between two plates with matching channels/ grooves which are fastened together. In the clamped configuration, thermal grease can be used to increase the contact of the heat pipe to the plates to reduce the thermal resistance of the contact interface, just as the thermal epoxy and solder did in the prior example.



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WAKEFIELD-VETTE STANDARD HEAT PIPES

Wakefield-Vette offers individual Heat Pipes through distribution. These most common offerings are a great option for testing, sampling, and validating your heat pipe solution into eventual production.

When building or testing your heat sink assembly please feel free to contact one of Wakefield Vette's authorized distributors to purchase. Always remember to contact us for free consultation on assembly design or parameter questions.

Wakefield-Vette Part Number	Description
121686	Round Heat Pipe 4 x 70mm
121687	Round Heat Pipe 4 x 100mm
121688	Round Heat Pipe 4 x 150mm
110578	Round Heat Pipe 6 x 100mm
110579	Round Heat Pipe 6 x 150mm
110580	Round Heat Pipe 6 x 200mm
110581	Round Heat Pipe 6 x 250mm
110582	Round Heat Pipe 6 x 300mm
121968	Round Heat Pipe 8 x 100mm
110583	Round Heat Pipe 8 x 200mm
110584	Round Heat Pipe 8 x 250mm
110585	Round Heat Pipe 8 x 300mm
121689	Round Heat Pipe 10 x 100mm
121690	Round Heat Pipe 10 x 200mm
121691	Round Heat Pipe 10 x 250mm
121692	Round Heat Pipe 10 x 300mm
121716	Flat Heat Pipe 2.5 x 100mm
121717	Flat Heat Pipe 2.5 x 150mm
121718	Flat Heat Pipe 2.5 x 200mm
121719	Flat Heat Pipe 2.5 x 250mm
121720	Flat Heat Pipe 3 x 100 mm
121721	Flat Heat Pipe 3 x 150 mm
121722	Flat Heat Pipe 3 x 200 mm
121723	Flat Heat Pipe 3 x 250 mm
121724	Flat Heat Pipe 3 x 300 mm
121725	Flat Heat Pipe 4.5 x 100mm
121726	Flat Heat Pipe 4.5 x 150 mm
121727	Flat Heat Pipe 4.5 x 200 mm
121728	Flat Heat Pipe 4.5 x 250 mm
121729	Flat Heat Pipe 4.5 x 300 mm
120231	Ultra Thin 6MM DIA X 1.50MM
120229	Ultra Thin 5MM DIA X 1.00MM

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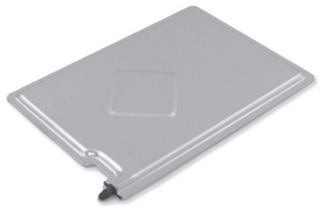
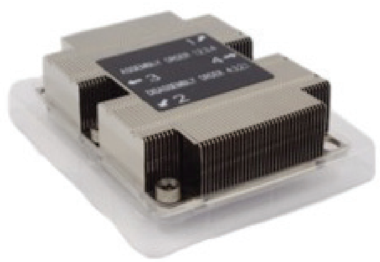
VAPOR CHAMBER DESIGN GUIDE

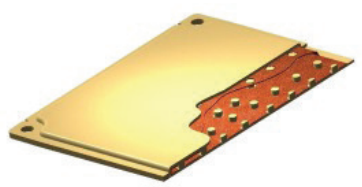


VAPOR CHAMBER INTRODUCTION

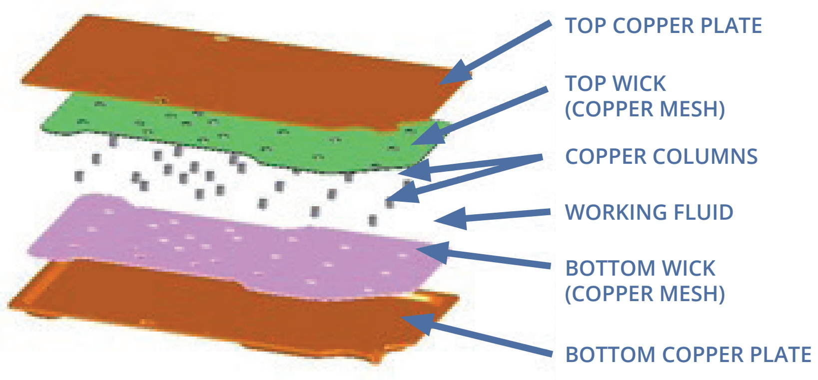
Vapor Chambers are used to transport heat over a distance with very low thermal resistance. This is very helpful when small heat sources need to be dissipated over a larger area. Vapor chambers are a **Fluid Phase Change application** because they use a closed loop to transfer heat quickly through evaporation and condensation within the chamber. The particular aspect useful in designs is that vapor chambers transport heat in a plane, more effectively "spreading heat" compared to a heat pipe which transports heat over a distance in a straight line.

Vapor chambers, like heat pipes, do not actually dissipate the heat to the environment, but serve to move heat efficiently within a thermal system. A vapor chamber is made from copper plates (top and bottom) with an internal wick structure that is sealed around the perimeter with a small amount of water inside. As heat is applied to the chamber, the water will boil and turn to a gas, which then travels to the colder section of the vapor chamber, where heat is dissipated through an external heat exchanger, where it condenses back to a liquid. It is the evaporating and condensing of the water that form a pumping action to move the water (and thus the heat) from the area of the heat source to all other areas of the vapor chamber.





There are a few types of wick structure that can be used within the vapor chamber, but most commercial chambers are classified as mesh or powder. In both cases, the powder or mess line the copper plate surfaces to allow water flow to/from all directions within the area of the vapor chamber. Often, when mesh is used as the wick structure, different sized meshes are used together to promote condensation or transport of liquid depending on the void size. Vapor chambers are best used in horizontal orientations. The effects of gravity may vary depending on application and orientation, but one must consider lower performance if used above 15° out of horizontal.



During the manufacturing process copper columns are used throughout the vapor chamber to support the plates that act as the lids and contain the liquid and vapor. The copper mesh is oriented within the chamber pressed against the copper plates. The plates are sealed around the perimeter via diffusion bonding. In some cases, soldering or welding are used, but diffusion bonding allows for the strongest and highest temperature compatible seal for the vapor chamber. The diffusion bonding process also allows the mesh to bond to the copper plates as well.

WHY USE VAPOR CHAMBERS?

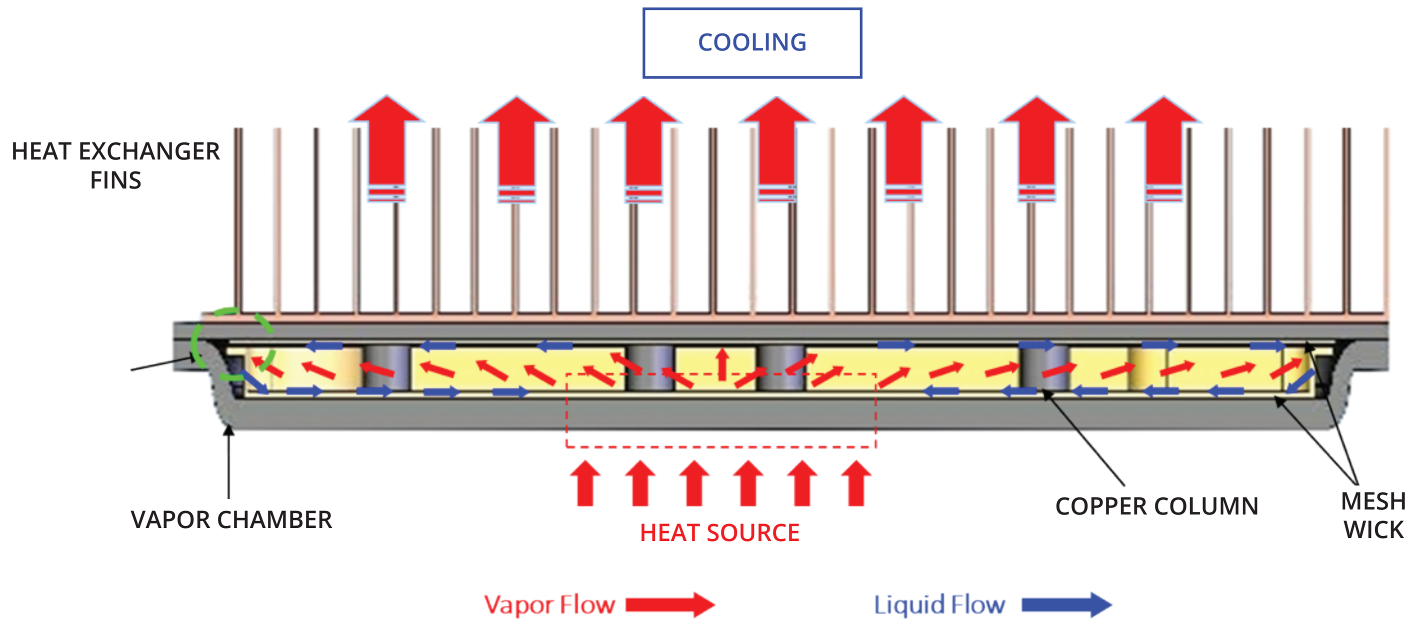
Vapor chambers have proven to be robust and reliable over many years in these types of applications. The next section will give more technical detail on the performance of vapor chambers depending on thickness and area. Many thermal systems benefit from the addition of vapor chambers, especially when heat sources are dense and the final heat exchanger is much larger and the heat from the source must be spread to a larger area effectively to efficiently use the heat exchanger. Computer applications, such as processors, graphics cards and other chip-sets, have high thermally dissipated power in a small area. Fan heat sink combinations used in these applications can offer high-performance dissipation to the ambient, but much of the battle is to spread the heat to the heat exchanger with as little temperature change as possible. Vapor chambers excel at this and can transport large heat loads from small areas with very little temperature difference.

Vapor chambers are used in many harsh environments such as:

- Computers and Data Centers
- Telecommunications
- Aerospace
- Transportation

KEY FEATURES
• Material: Copper • Wick Structure: Copper Mesh • Light Weight • Versatile with high thermal performance

HOW VAPOR CHAMBERS OPERATE



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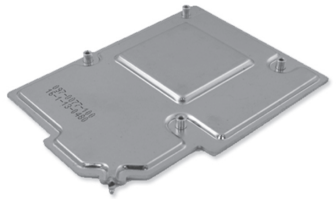
VAPOR CHAMBER DESIGN GUIDE

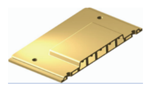


VAPOR CHAMBER BASICS

When considering the use of a vapor chamber in your application, it is important to consider the orientation with respect to gravity and overall heat load for the thermal system. The transport of vapor within the vapor chamber is responsible for the thermal conduction from one area to the other. A thicker vapor chamber can transport more vapor, translating into a larger heat carrying capacity. Although vapor chambers can have complex shapes and mounting features, they are not typically bent and integration can be more direct with the heat source than with heat pipes.

VAPOR CHAMBER BASICS

- Comparison to Heat Pipes
- Transport
- General parameters



VAPOR CHAMBER		HEAT PIPE
2-Phase heat transfer	Theory	2-Phase heat Transfer
2-D heat distribution. Spreading heat by a single vapor chamber. Suitable for large heat flux and high power.	Application	1-D heat distribution. Using one or more heat pipes to spread heat. Suitable for long distance between heat source and heat exchanger.
Complex shape in X and Y direction with pedestal.	Shape	Round, flattened or bent in any direction.
Mounted with through-holes in vapor chamber	Fixtures	Additional fixure plates needed to mount heat pipes.
Direct contact. Mounting pressure to 90PSI	Heat Source Contact	A base plate required to contact the heat source unless flattened/machined.
T=5mm > 400W; T=3mm > 200W; T=1mm > 60W	Qmax	Ø5 > 20W; Ø6 > 40W; Ø8 > 60W
Vapor chamber has larger tooling cost so high volume applications can lower cost to ~2X heat pipe. However, solution may need only 1 vapor chamber compared to many heat pipes and fixture/base plates.	Cost	Lower cost for a single heat pipe, but may also need tooling cost for bending/flattening.

In many applications, the decision to use a vapor chamber is frequently compared to a thermal solution using heat pipes. In both cases, 2-phase transport is used as a vapor moves heat within the chamber or pipe and the liquid is condensed at the heat exchanger and transported back to the heat source. However, the main aspects of applications that differentiate vapor chambers from heat pipes are:

- High power density: when the heat source is small but heat generation is large, vapor chambers can more easily transport the heat to a larger area. A heat pipe solution would require multiple pipes, which may be difficult to integrate within the footprint of the heat source.
- High power: when the application must dissipate large wattage, a vapor chamber spreads the heat to a large area efficiently with similar temperatures of the chamber surface. This allows more efficient use of the final heat exchanger since hot spots are minimized. Heat pipes can also spread the heat, but unless many are ganged together, the hot spots may still persist.

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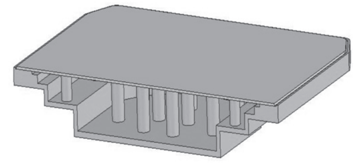
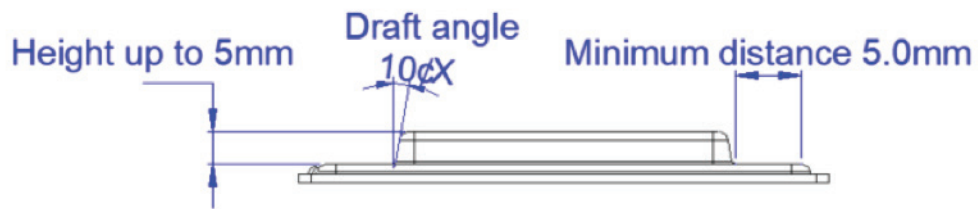
VAPOR CHAMBERS THERMAL CAPACITY

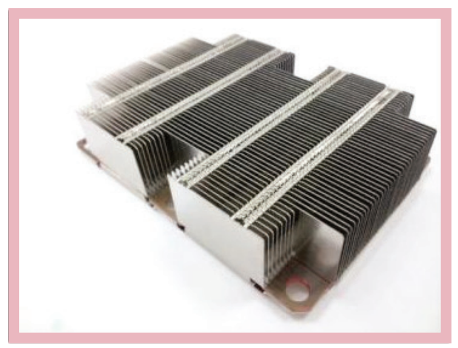


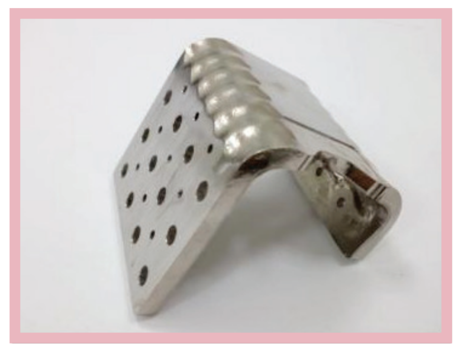
Much like heat pipes, the ultimate dimension in determining heat carrying capacity of a vapor chamber is the volume of the vapor space. This is determined by the thickness and area of the vapor chamber. For most applications, the thickness of the vapor chamber does not exceed 3mm, however pedestals and other surface features can be used to contact specific heat sources while leaving clearance for other board mounted objects. These pedestals can be extended 5mm from the vapor chamber lid plate. Mounting holes can also be integrated within the area of the vapor chamber for better integration with the heat source and locating the heat source a the center of the vapor chamber with good pressure application.



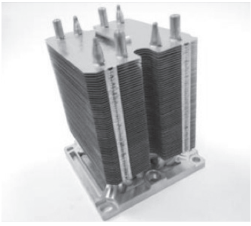
	HEAT CARRYING CAPACITY (Q-MAX) BY VAPOR CHAMBER THICKNESS							
	1.0mm	1.2mm	1.5mm	2.0mm	2.3mm	2.5mm	3.0mm	>3.0mm
45*45	10W	15W	20W	25W	60W	80W	100W	>100W
90*90	40W	50W	80W	100W	150W	180W	250W	>300W
120*120	40W	50W	80W	100W	160W	200W	275W	>300W
150*150			80W	100W	170W	220W	300W	>300W
200*200				100W	175W	225W	>300W	>300W
250*250					180W	240W	>300W	>300W
300*300								>300W

Note: Heat source = 30*30mm
This table is for reference. Q-max is related to heat source power density and effectiveness of final heat exchanger.



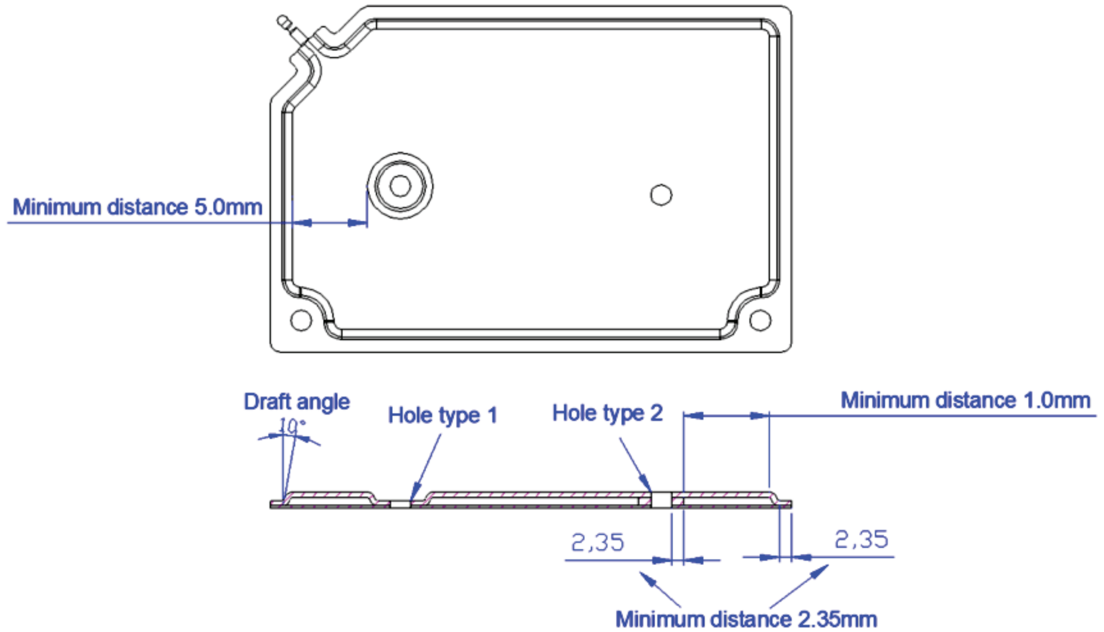


VAPOR CHAMBER DESIGN GUIDE

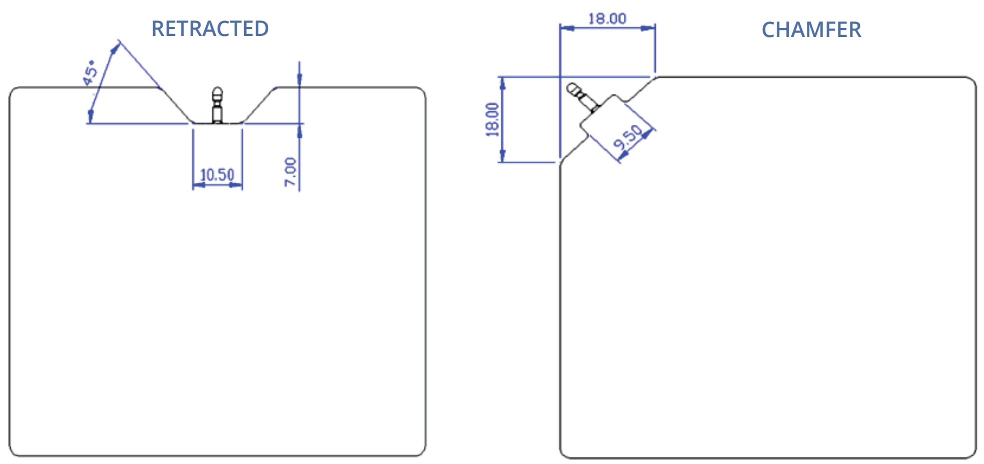


VAPOR CHAMBER ASSEMBLIES

Interfacing vapor chambers with plates and heat exchangers is predominately about maximizing contact area. In most cases, the vapor chambers are soldered to heat exchanger fins for air cooled applications. The vapor chambers can also be soldered to liquid cold plates to take advantage of spreading the heat before final heat exchange with the liquid. In many cases, the vapor chambers are also integrated with heat pipes to take the heat that has spread in the plane of the vapor chamber and extend it in the vertical dimension to more efficiency interact with cooling fins. Integrating with the heat source is most commonly done with pressure, up to 90 psi, and the use of a thermal grease or other interface material to maximize surface area contact to the source.



2 TYPES OF FILLING PORTS (7MM MAXIMUM):



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WAKEFIELD-VETTE STANDARD VAPOR CHAMBERS

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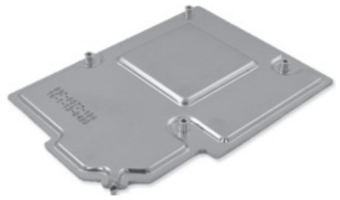
WKV Part #	Product Description	Thermal Resistance	Length	Width	Thickness	qMax
VC-1131-8175-517	Standard Vapor Chamber 113.1mm x 81.75mm X 5.17mm	0.145	113.1	81.75	5.7	180W~
VC-90-90-3	Standard Vapor Chamber 90mm x 90mm x 3.00mm	0.143	90	90	3	150W~
VC-106-70-3	Standard Vapor Chamber 106mm x70mm x 3mm	0.150	106	70	3	150W~
VC-106-82-3	Standard Vapor Chamber 106mm x 82mm x 3mm	0.140	106	82	3	150W~



PART NUMBER VC-1131-8175-517

Product Info Description
Dimension(mm): L: 113mm / W: 81.8mm / T: 5.7mm
Operation Power: 180W~

Product Info Details
Thermal Resistance: 0.145°C/W
Operation Temp: 40~130°C
Platform : VGA

PART NUMBER VC-90-90-3

Product Info Description
Dimension(mm): L: 90mm / W: 90mm / T: 3mm
Operation Power: 150W~

Product Info Details
Thermal Resistance: 0.143°C/W
Operation Temp: 40~140°C
Platform : Intel 2011 Square

PART NUMBER VC-106-70-3

Product Info Description
Dimension(mm): L: 106mm / W: 70mm / T: 3mm
Operation Power: 150W~

Product Info Details
Thermal Resistance: 0.150°C/W
Operation Temp: 40~140°C
Platform : Intel 2011 Narrow

PART NUMBER VC-106-82-3

Product Info Description
Dimension(mm): L: 106mm / W: 82mm / T: 3mm
Operation Power: 150W~

Product Info Details
Thermal Resistance: 0.140°C/W
Operation Temp: 40~140°C
Platform : Intel 2011 Narrow